

# COMPUTER AND BROADBAND TECHNOLOGY IN AIRCRAFT LINE MAINTENANCE: A TASK ANALYSIS AND QUESTIONNAIRE

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## ABSTRACT

The line maintenance work process was documented at two major air carrier facilities. This analysis shows how computer and broadband technology is used in most every phase of the line maintenance process with one important exception: maintenance technicians at neither carrier used technology on the ramp when performing maintenance on aircraft. We devised a questionnaire to query technicians' attitudes about their work process and whether or not their work could be improved by the use of technology. Questionnaire responses suggest three specific ways in which computer and broadband technology might support the performance of maintenance tasks.

## TASK ANALYSIS

In previous studies, interviews have been used to determine those aspects of the maintenance process in which computer and broadband technology are presently being used, and what impact these technologies have on the work process [Casner and Puentes, 2003; Iyengar et al, 2004]. One limitation of the interview methodology is that it is generally difficult for technicians to recall all phases, aspects, and details of their work process during a brief conversation with an interviewer.

In this study, we documented the work process at line maintenance facilities of two major air carriers by observing technicians as they worked during regular work shifts. These observations were used to create a detailed description of the steps required to plan for and execute line maintenance required for the typical inbound flight. For each step in the work process, we noted all computer and broadband technologies that were used.

The task analysis was created during a series of four visits to two different air carrier maintenance facilities. During each visit, we were permitted to follow a single line maintenance crew consisting of two maintenance technicians for the duration of their work shift. We were allowed to follow the crews wherever they went and ask questions at any time.

### Arriving On Shift

Maintenance technicians arrive to work, gather tools and safety gear, and learn two important things that will chart the course of their work shift: (1) who their partner will be for the shift; and (2) which scheduled flights they are assigned to meet, along with the gates at which the flights will arrive. Partner and flight assignments are made by the lead technician, prior to the arrival of the other technicians.

### Planning and Preparation

Once the technicians know to which flights they have been assigned, they can begin preparing for the arrival of each aircraft. The maintenance tasks that must be performed on each aircraft can come from a variety of sources. Before the arrival of each flight, technicians become aware of two types of required maintenance tasks.

#### *Routine Checks*

A routine check is a basic walk-around of an aircraft that is required for most every incoming flight. Technicians must follow a published procedure for this check. These procedures are found in the maintenance manual for each type of aircraft.

Technology In Use: Maintenance manuals are stored in electronic format and are available on any of several computer workstations found in the maintenance office. Technicians must look up the procedures in the computer then print out a copy to be carried out to the aircraft when the procedure is performed. Casner and Puentes (2003) found electronic documentation systems to be used at every maintenance facility surveyed. Electronic documentation systems appear to solve a number of problems suffered by traditional paper manuals. First, technicians no longer have to wait to use a limited number of copies of any one manual: any manual can be accessed by any number of technicians at once when a computer terminal is available. Second, electronic documentation allows technicians to access any number of different manuals at a single computer workstation. Third, manuals can be revised electronically in a matter of minutes, and is a less error-prone process. For these reasons and others, electronic documentation systems enjoy widespread acceptance among technicians and managers.

### *Assigned Maintenance Tasks*

All maintenance activities that occur across the company are monitored and managed by a central maintenance organization that manages all aircraft in the fleet as they travel from airport to airport. This organization can assign maintenance tasks to be performed upon arrival at particular airports. The local technicians are responsible for completing the assigned task(s) when the flight arrives.

An assigned maintenance task usually represents a known problem with the aircraft that might require troubleshooting, parts replacement, and/or significant work. Upon learning about assigned maintenance tasks, technicians can prepare in advance for the arrival of the aircraft. Technicians must gather three important resources that will allow them to perform the maintenance task: (1) documentation; (2) parts; and (3) tools. Documentation includes the relevant pages of the maintenance manuals and parts catalogs relevant to the task. These pages must be carried out to the aircraft when the work is performed. To gather parts, the technician must learn the relevant part numbers, determine if the parts are available from the company parts inventory, then retrieve the parts. Part numbers can be identified from the illustrated parts catalog (IPC). Typically, if maintenance control assigns a maintenance task, they will arrange to have needed parts delivered to the maintenance facility in advance. Once the technician verifies that the needed parts are available, s/he must walk over to the parts storage and retrieve the parts. If special tooling is needed to perform the maintenance task, these tools must be retrieved from a tool storage facility also located on the airport ramp. Once all documentation, parts, and tools are gathered, they can be loaded on a cart that will be driven out to meet the aircraft when it arrives.

Technology In Use: Technicians learn about assigned maintenance tasks by using a maintenance management software system installed on the computer workstations in the maintenance office. When a technician is assigned to work a scheduled flight, the technician must enter the flight number into the maintenance management software system. The system will then display all maintenance tasks that have been assigned by maintenance control.

Documentation such as maintenance manuals and illustrated parts catalogs are stored electronically. Pages from these manuals can be printed. Another software system allows technicians to look up part numbers and quickly determine whether or not a part is available at the facility. The system also tells

technicians where the part is located in the parts inventory.

### **Arrival At The Gate**

Just prior to the scheduled time of arrival for each aircraft, technicians drive the cart equipped with documentation, parts, and tools out to the gate to which the incoming aircraft has been assigned.

### *Maintenance Problems Reported By The Flight Crew*

After completing some of the routine check, technicians typically enter the cockpit to greet the flight crew. As the crew finishes their duties, technicians query the flight crew about any maintenance issues that arose during the flight. Although the crew is required to fill out a maintenance sheet for each maintenance discrepancy, the conversations between technicians and flight allow much more information to be exchanged than what is typically written on a maintenance sheet. Specifically, the expert technicians are able to ask questions of the flight crew to clarify or give more details about maintenance problems.

Technology In Use: As an incoming flight comes within radio communication range of the airport, the flight crew can call in other maintenance problems they have experienced. These in-range calls are designed to give maintenance technicians extra time to prepare for unexpected maintenance tasks. These calls are made via VHF radio transmissions from the cockpit to the lead technician in the maintenance office. Once received in the maintenance office, this information is passed on to the technicians that have been assigned to meet the aircraft. Upon learning about these maintenance problems, technicians must quickly go through the same preparatory routine they have done for any assigned maintenance tasks: gathering documentation, parts, and tools.

### *Maintenance Problems Discovered During Routine Checks*

Technicians then complete the walk-around of the aircraft. This routine check represents another source of maintenance discrepancies and tasks: those discovered during the routine check.

Technology In Use: Many airplanes contain onboard diagnostic computers that can automatically detect faults during the flight. Technicians access this information after the crew leaves and they complete their cockpit checks. This represents another class of maintenance problems: those detected by the computer but that were unknown to the flight crew.

At this point, the technicians now know about all of the maintenance problems that they will have to deal with during the airplane's stay at the airport. To recap, these problems have come from four different sources:

1. Tasks assigned by maintenance control
2. Problems discovered during routine checks
3. Problems reported by the flight crew (in-range or on the ground)
4. Problems reported by the airplane's on-board diagnostic computers

### **Troubleshooting and Solving Maintenance Problems**

Confronted with a list of maintenance tasks, technicians have one overriding goal: to do everything possible to ensure that the aircraft is able to depart on schedule. There are two basic ways to address each maintenance problem: (1) deferring the problem; or (2) resolving the problem.

#### *Deferring Maintenance Problems*

Many types of maintenance problems can be deferred for specified periods of time. This is the most desirable option for problems other than those that can be resolved quickly. Deferral allows the aircraft to depart on schedule, and also allows maintenance control to assume responsibility for the maintenance problem. Recall that maintenance control commands all of the technical resources of the entire company. A deferral allows maintenance control to determine which of the aircraft's upcoming stops would be best suited for a particular type of maintenance problem. Maintenance control can choose an airport that has the most appropriate technicians, arrange to have needed parts or tools made available, and choose the stop that offers technicians the most time to work on the problem.

To defer a maintenance problem, the crew must determine whether or not the problem is legally deferrable. A document called a minimum equipment list (MEL) records the list of parts that can be inoperative for any aircraft. If a maintenance problem amounts to an inoperative part, and that part can be found on the minimum equipment list (MEL), technicians can legally defer the problem and the aircraft can depart on schedule.

#### *Resolving Maintenance Problems*

There are two kinds of maintenance problems that are not deferred: (1) those that are not deferrable according to the minimum equipment list (MEL); and (2) those that have previously been deferred, and can be deferred no longer. Tasks that are assigned by maintenance control are typically of the second

variety: tasks that were deferred by technicians during previous stops.

Resolving a maintenance problem represents the real work of the maintenance technician. Technicians must now use their knowledge and skills to isolate and remedy each problem. Technicians have a variety of resources available to them when resolving a maintenance problem.

#### **Documentation Resources**

Technicians have several documentation resources available to them when resolving a maintenance problem. A fault isolation manual (FIM) prescribes a series of steps to be used when troubleshooting a problem. The steps in the FIM involve replacing parts, one after another, until a faulty part is found and replaced and the system functions normally again. When replacing each part, technicians must return to the maintenance office, look up the part number, determine if the part is in stock, then return to the airplane to replace the part. If this part turns out not to be the defective part, these steps must be repeated. In many cases, if a part is replaced and it does not result in a fix, that part remains in the aircraft and the old part is retired, or must be recertified before it can be used again in another aircraft.

In the case that the procedure in the fault isolation manual does not result in resolution of the problem, technicians must resort to other troubleshooting resources. Circuit diagrams allow technicians to trace through electrical circuits when troubleshooting.

Technology In Use: Documentation is stored electronically and available at the computer workstations in the maintenance office. At one of the maintenance facilities, laptop computers were available. These computers allowed technicians to access documentation and make entries into the maintenance management software remotely. We did not observe a single instance of a technician using these computers.

#### **Other Technicians**

A variety of human resources are available to technicians when working on a problem. Technicians can consult with other technicians working on other aircraft on the ramp. Technicians can call the lead technician and ask for assistance. Maintenance control offers technical assistance on any maintenance topic via telephone.

Technology In Use: Technicians often use company radios or personal cell phones to talk when away from each other.

## Wrapping Up

After work is completed at the aircraft, technicians return to the maintenance office and make entries in the maintenance records for the aircraft. In the case of a deferral, the technician records the deferral. In the case that a problem is resolved, the technician records all of the maintenance actions that were taken, and certifies that the aircraft can be returned to service. In the case that a problem is neither deferred nor resolved, the aircraft must be grounded.

**Technology In Use:** Technicians make entries into maintenance records using the same maintenance management software. This system makes the maintenance just performed available to technicians and managers across the company.

## QUESTIONNAIRE

The analysis above describes how broadband and computer technologies are used in most phases of the line maintenance process except for one: troubleshooting and solving maintenance problems. To investigate the reasons for why technology is not used in this central part of the maintenance process, we developed a paper and pencil questionnaire.

Questionnaire items were designed to explore three questions raised by our task analysis:

1. Do technicians feel that current documentation systems well support the performance of maintenance tasks?
2. How much importance do technicians place on each others' expertise, and how well does current technology support the sharing of expertise?
3. Are technicians open to the idea of using computer and broadband technology while working out on the ramp?

## Participants

Sixty-eight maintenance technicians participated in the study on a voluntary basis. Technicians who completed the questionnaire were given a NASA t-shirt as compensation.

## Apparatus

The questionnaire contained thirty-four questions and covered both sides of a single sheet of paper. The questionnaire items, listed below, were designed to probe technicians' opinions about the resources they currently have available to them when resolving maintenance problems, and what resources they might find desirable in the future. Since our focus was on technological resources, our questionnaire also queried

technicians about their experience with computers and broadband technology.

Each questionnaire item made a statement about resources that might be used during line maintenance, and asked participants to agree or disagree with the statement using a five-element Likert-type scale.

## Questionnaire Items

1. When troubleshooting a problem, the fault isolation manual (FIM) usually provides everything I need
2. The FIM is usually the best way for an experienced technician to troubleshoot a problem
3. The FIM is usually the best way for an inexperienced technician to troubleshoot a problem
4. I often use other sources of information (i.e., wiring diagrams) in addition to the FIM
5. I always follow the steps in the FIM exactly as written
6. I often consult with other technicians
7. I often consult with maintenance control
8. I often consult with the lead or supervisor
9. I can often provide information to other technicians that can help them troubleshoot a problem
10. Other technicians often provide me with useful information
11. Someone on my shift always knows the answer to my question
12. Experienced technicians often provide better information than the manuals
13. Different technicians excel in different areas of expertise
14. Technicians should learn to find the information rather than asking me for it
15. Technicians can learn a lot just by talking to each other
16. I would rather use the manuals than ask another technician
17. Communication between technicians at our facility is adequate
18. We should have a better way for technicians to talk to each other at our facility
19. I often use company radios to talk to other technicians on the ramp
20. If other technicians have already solved a difficult maintenance problem, I'd like to have their notes in front of me when I'm dealing with that same problem
21. It would be nice to have some kind of searchable database of difficult maintenance problems

22. This searchable database should allow technicians to enter any relevant notes about procedure, tooling, etc.
23. A searchable database should allow us to use any keywords, like a web browser
24. Searching maintenance histories using ATA codes alone is too limiting
25. I would be willing to submit information about difficult maintenance problems to this database
26. I think most other mechanics would be willing to submit information to this database
27. Finding information in the computerized maintenance manuals is relatively quick and easy
28. I wish the manual were more easy to search or use
29. I wish there was a way to more quickly access needed information when I'm out at the aircraft
30. There should be an easier way for me to access frequently-used information like tire pressures and torque values (e.g., a "quick reference")
31. Having a quick reference for frequently-used information would increase my productivity
32. I would use a PDA (e.g., Palm Pilot) to access maintenance information at the aircraft
33. I would use a laptop computer to access maintenance information at the aircraft
34. Using computer equipment of any kind or size at the aircraft is cumbersome

### Procedure

Questionnaires were distributed to line maintenance technicians working at three different facilities operated by the same airline company. Questionnaires were handed to line maintenance technicians at the beginning of several work shifts by the lead technician who served as supervisor for the shift.

### Results and Discussion

Figure 1 shows the mean and standard deviation for responses given to each questionnaire item. These statistics were derived by numerically coding the five-element Likert-type scale used to elicit responses from participants. Scores of 1 through 5 were assigned to responses of Strongly Disagree, Disagree, Neutral, Agree, and Strongly Agree, respectively.

*Do technicians feel that current documentation systems support the performance of maintenance tasks?*

In response to item 4, technicians agreed that they used other documentation materials besides the fault

isolation manual (FIM) (e.g., wiring diagrams) when troubleshooting problems [4.24 (0.8)]. Technicians provided the strongest response to item 29, indicating that they wanted a means of more quickly accessing these resources when out at an aircraft [4.33 (0.61)]. Item 30 indicated that technicians wanted an easier way of accessing frequently-used information, while item 31 showed that technicians believed that having this quick access would increase their productivity.

**ANALYSIS:** Although electronic documentation enjoys good acceptance overall [Casner and Puentes, 2003] and seems to well support the maintenance planning process, the current use of computer workstations in the maintenance office may not well support the sometimes iterative process of troubleshooting and solving problems. Having to walk back and forth between office and aircraft seems to be a burden for technicians. Questionnaire responses suggest the need for a means of remotely accessing electronic documents while working on the ramp.

In addition, technicians expressed the need to have some information items, found within a document, to be more readily accessible. In our earlier interviews [Casner and Puentes, 2003], technicians often complained about having to access manual pages in the computer for numbers that they use everyday.

*How much importance do technicians place on each others' expertise, and how well does current technology support the sharing of expertise?*

Item 6 was the most direct (I often consult with other technicians) and received an average response of 3.96 (0.76). Responses to items 9 and 10 suggest that technicians generally agree that they have valuable information to share with other technicians, and that they benefit from information provided by other technicians. Technicians strongly responded to item 13, that different technicians excel in different areas of expertise [4.13 (0.8)], and to item 15: that technicians can learn a lot from talking to one another [3.91 (0.64)].

**ANALYSIS:** Responses to these questionnaire items indicate that communication among technicians is a core part of the maintenance crews' problem-solving capability. It is important to note that sharing of expertise can happen on two different time-scales. As indicated by item 19, technicians sometime use radios to talk to each other while working on the ramp. We saw many instances of cell phone use for the same purpose. This allows technicians to communicate with one another on a minute-by-minute basis: asking simple questions and coordinating movements while

out on the ramp. But sharing of expertise can also happen on a wider time scale: the idea of passing on information gained through experience to crews working future shifts or crews at different locations. Items 21, 22, and 23 addressed this idea by probing technicians' interest in having some sort of searchable database that provides case-specific information about

previous difficult maintenance problems. Technicians generally agreed that they would like to have such a system [4.0 (0.85)], that this database should allow technicians to enter relevant notes about each case [4.01 (0.66)], and that the database should be searchable using keywords, like a web browser [4.1 (0.63)].

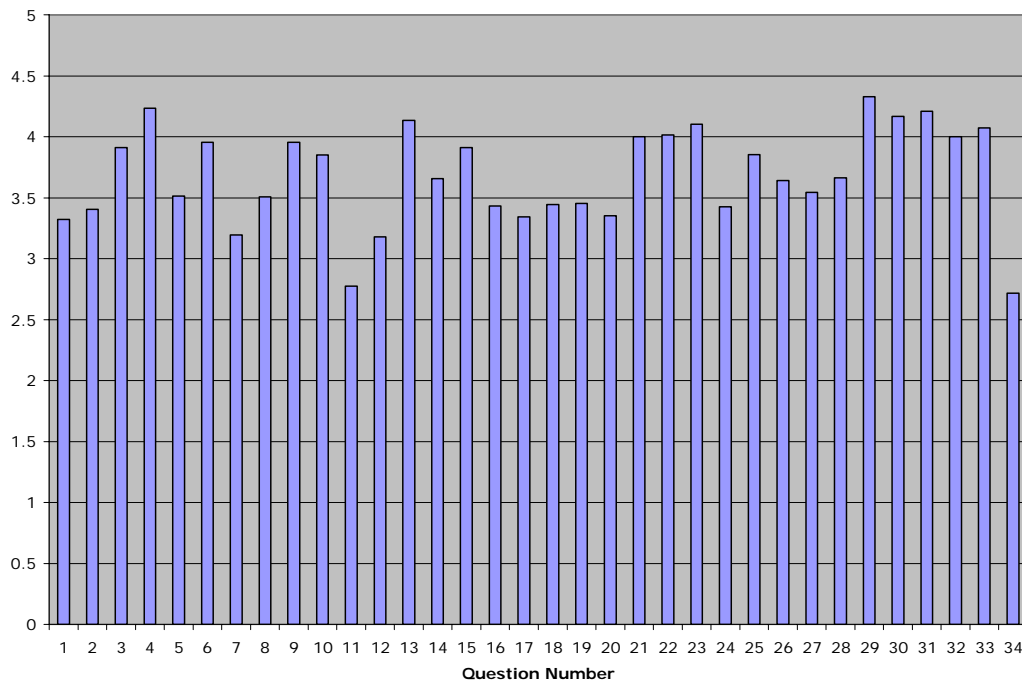


Figure 1: Average responses to questionnaire items

*Are technicians open to the idea of using computer and broadband technology while working out on the ramp?*

Questions about technicians' willingness to use portable computer technology on the ramp was motivated by our observation that technicians had laptop computers available at one facility, but did not use them.

Item 33 directly asked technicians if they would be willing to use laptop computers on the ramp. This questionnaire item yielded a response of 4.07(0.8), a result contrary to what we observed.

Item 32 asked technicians if they would consider using a PDA device while working at the airplane. The average response was 4.0 (Agree), and there was no difference between technicians who had [3.92 (0.93)]

and had not [4.05 (0.82)] previously used PDA devices.

**ANALYSIS:** Despite the agreement that portable computers would be useful, our task analysis revealed no use of such devices, even though wireless laptop computers were available to technicians at one of the facilities we visited. We interpret this lack of use as an indication that the portable computers fail to offer the functionality, usability, or reliability that technicians seek in such a device.

## CONCLUSION

To summarize, we draw three conclusions from what we observed during the task analysis and the responses to the questionnaire.

First, although current electronic documentation systems solve many problems suffered by traditional paper manuals, it seems that current documentation

systems could evolve in specific ways. First, documentation should be accessible by means other than the computer workstations located in the maintenance office. Technicians expressed a need to access manuals while working out on the ramp. Second, it does not appear that current documentation systems fully exploit the advantages of the digital medium. In many cases, manuals are simply digitized versions of a paper manual. Technicians expressed a need to more quickly search for frequently-used items in the manuals. This suggests document search functionality that goes beyond the typical index and table of contents. This functionality might even extend to the idea of a document that dynamically reorganizes itself depending on how the document is searched and used over time.

Second, observations and questionnaire responses strongly suggested that technicians rely on each other when solving maintenance problems. Our observations showed that technicians frequently use cell phones and company radios to talk with one another while working on the ramp. Technicians also make use of a telephone help system that allows them to call the company's maintenance control facility to get advice from other technicians who specialize in particular areas. Questionnaire responses indicated that technicians would like one additional resource: a database system that allowed them to access notes left by other technicians from previous maintenance problems. Such a system would provide yet another means of sharing expertise between technicians.

Questionnaire responses indicated that technicians would not only use such a system, but also be willing to submit their own notes to such a system.

Third, with regard to using portable computers while working on aircraft, questionnaire responses contradicted the behavior we observed during the task analysis. Technicians claimed they would be willing to use portable computer, yet did not use them in practice when they were made available. This suggests that the design of presently-available portable computers does not match what technicians are looking for in such a device.

#### Future Work

With these three conclusions in mind, we have begun prototyping a hardware/software tool (illustrated in Figure 2). The purpose of this tool will be to explore the idea of providing technicians with the capabilities that they appear to need and have claimed to want. This tool, implemented on a PDA device, will evaluate the feasibility of offering technicians three capabilities:

1. Portable access to existing maintenance documentation;
2. A means of more quickly accessing frequently-used documentation items;
3. A means of searching and contributing to an archival database of previous maintenance cases;

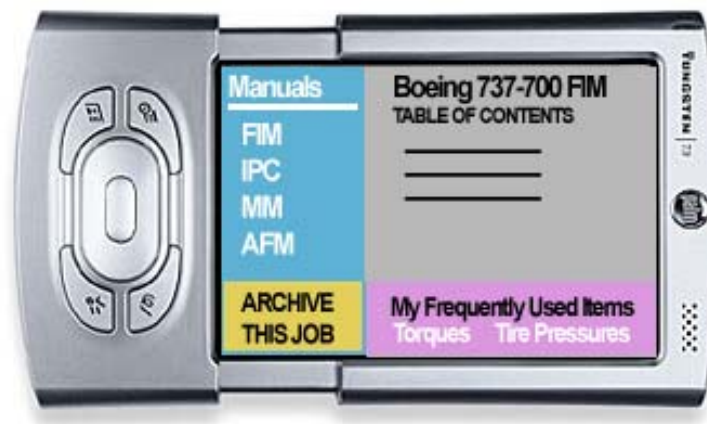


Figure 2: Prototype portable tool

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